TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 476

SYNOPSIS OF FRENCH AERONAUTIC EQUIPMENT

Aeronautic Instruments

From L'Aéronautique, No. 100
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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL MEMORANDUM NO. 476

SYNOPSIS OF FRENCH AERONAUTIC EQUIPMENT.*

Aeronautic Instruments

Aeronautic instruments should be of sturdy construction, easy to keep in repair, of minimum bulk and weight, and easy to install. Encased instruments must be provided with standard attachment collars of 120 mm (4.72 in.) diameter with six equidistant holes 5 mm (0.2 in.) in diameter. For some instruments (watches) these dimensions can be reduced. The cases must be made of some light alloy. The mechanisms must be well balanced and unaffected by electromagnetic fields. The dials and pointers must be luminous.

Control Instruments

These are intended to assure safety and regularity of flight and, if used intelligently, will result in greater efficiency and enable a saving of fuel.

Air-speed indicators.- These instruments, in standard cases, measure a pressure of $H = \frac{\delta V^2}{2 g}$. They indicate the true speed of

*"Tableau des Equipments et Accessoires de l'Aéronautique Francaise" in L'Aéronautique, No. 100, September, 1927.
We are here publishing Chapter 3 of this "Synopsis," the first two chapters, devoted to the equipment for the pilot cockpits, passenger cabins, and aerial photography, having appeared in our June number. For the following descriptions, we must again acknowledge our indebtedness to Paul Mazer, aeronautic engineer, for his valuable cooperation.

the aircraft, when the atmospheric pressure is 760 mm (29.92 in.) Hg, the temperature 15°C (59°F.) and the air density δ. They comprise:

1. An aerodynamic tube, which may be either a Venturi tube (double or single) for speeds below 200 km (124 mi.) per hour, or a simple Pitot tube with a static tube for high speeds. The tube must be located away from every eddy and region of under-pressure or over-pressure and so that rain or fog will not interfere with its proper functioning.

2. An indicator, connected with the tube by annealed brass pipes, with ends suitable for attaching rubber tubes. There are three types of indicators: 60-200 km (37-124 mi.) per hour; 60-260 km (37-161 mi.) per hour; and 80-300 km (50-186 mi.) per hour. The difference E between the true speed V and the indicated speed V_1 must not exceed:

a) For the Venturi tube, $3V/100$, if V is under 150 km (93 mi.) per hour; $4V/100$, if V is over 150 km/h;

b) For the Pitot tube, $V/100$ for any value of V.

For studying the flight conditions of an airplane, the indications of the anemometer need to be recorded. The recording stylus then moves on a cylinder rotated by clockwork. The Aéra Company makes the Badin anemometers. The Jaeger and Hue Companies have made instruments of this kind. Mr. Dugit has invented

an amemometer with an altimetric corrector. Toussaint and Lepere have made a recording anemometer of double receptive capacity, one subjected to the negative pressure of a Venturi tube and the other to the positive pressure of a Pitot tube.

Angle-of-attack indicators.- These are vanes which take the direction of the wind by turning about a fixed axis. They are used to enable flying at the best angle of attack and to avoid exceeding the critical angle of attack.

Constantin invented a very interesting indicator (Fig. 1), which is made by the Aéra Company. Two directive horizontal surfaces are mounted on a hinged trapezoid, which throws the axis of rotation of the indicator to the intersection of the nonparallel sides of the trapezoid. Since this axis is thrown very far back, we can easily measure slight variations in the angle of attack and have a good stability.

Lieutenant Estienne had an indicator with horizontal vanes made by the Impar Company. The rotation of the vanes operates a colored sector which indicates the values of the different angles.

The Estienne-Du Cluzel indicator (Fig. 2) made by the Impar Company indicates the angle of attack in terms of the deviation of the air filaments in the vicinity of the airplane cell. It consists of a horizontal rod, on the ends of which two small vanes are mounted. This rod is fastened in the middle to the

end of a lever oscillating about an axis which turns in the sides of a case and is balanced statically by a mass shown through the hole in the case. A toothed sector, connected with the lever, controls the axial pinion of the flywheel, which moves under an opening in the case. The inertia moments of the mobile masses are such that a strict dynamic stability is maintained. Furthermore, the oscillations produced by vibrations of the air filaments are very strongly damped by an air brake, shown in the rear opening, the piston of which is joined by a connecting rod to the end of the oscillating lever. The flywheel has an arbitrary graduation drawn on red, white and bright green sectors (for better visibility at several meters distance), indicating the speed by the color exposed, red for low speeds, white for the speeds of minimum tractional force and of minimum power (practically indistinguishable in the immediate vicinity of the zero on the white sector), and green for the high speeds. The instrument is attached by band clamps to the front of a strut, for example, as far removed as possible from the eddies produced by the propeller slip stream.

<u>Longitudinal inclinometers</u>.- These must show every pitching motion of the airplane about its center of gravity. The stability and sensitivity of the indicators must be those of a simple pendulum which would have a period twenty times as great as the longest oscillation period of the airplane. The Chauvin and

Arnoux and Aéra Companies make indicators containing a liquid column, the top of which moves in front of a graduated scale (Fig. 3). A suitable shape of the glass tube and the density of the liquid render them aperiodic. The Impar Company make a recording "clinograph," in which a pendular mass, damped by kerosene, controls an indicating needle.

Turn indicators.- These must indicate every turn of the airplane and give the value of the radius of the curve.

The Aéra Company makes a Badin turn indicator which combines, on the same plate, the air-speed indicator and the lateral inclinometer, consisting of a bent glass tube filled with a liquid in which a metal ball rolls (Fig. 4). The turn indicator proper consists of a ball-bearing gyroscope revolving in a longitudinal cage, likewise mounted on ball bearings. The gyroscope is made to rotate by maintaining a negative pressure inside the case with a Venturi-tube aspirator placed on the side of the fuselage. The outside air, drawn in by the negative pressure, strikes the peripheral vanes of the gyroscope. The cage carries a pointer, moving on a dial, and a recall spring which returns the pointer to zero. This spring yields to the gyroscopic reactions produced in the turns and measures the rapidity of the latter, the pointer moving toward the center of the turn.

Legend to Figure 4.- Aéra turn indicator (Badin patent). a, vertical section; b, front view with face removed; A, anemom-

eter; B, knob for adjusting sensitivity to turning; C, damping cylinder and piston; J, injector of air for actuating gyroscope; P, lateral inclinometer; R, inlet cock (from large blower); S, recall spring of index; T, gyroscope. c and d, examples of indications in turning. Index moves in the direction of turn and the ball in the direction of slipping.

The Carpentier Company has recently constructed a small electric motor, functioning under 24 volts, which can replace the gyroscope.

Lateral inclinometers must be used with turn indicators, to give an accurate idea of the lateral inclination of the airplane.

Stall indicators.- Lamp indicators, addressing themselves to the sense of vision; acoustic indicators; corrective devices, acting on the airplane controls.

De Guiche had an acoustic anemometer made which indicates speed variations by variations in sound: a rotating iron alternator, located in a streamlined body, is actuated by a windmill, and the musical sound, produced by the alternator, is emitted into a telephone receiver (See L'Aéronautique, No. 71).

The Odier and Bramson stall indicators cause a wind vane to act on the control stick by the intermediation of a servo-motor with pneumatic relay (L'Aéronautique, No. 89).

Accelerometers.- Invented for determining the stresses of an airplane during its evolutions, the types used in France are ver-

tical accelerometers which render it possible to record stresses perpendicular to the wings.

Huguenard, Planiol and Mangan constructed an accelerograph containing a column of mercury. The accelerations are transmitted, by the intermediation of a manometer, to a stylus moving over a recording cylinder (Fig. 5).

The Badin, Impar and Lemoine accelerometers consist of tared masses suspended by springs (Fig. 6).

Navigation Instruments

These must make it possible to fly from one point to another, to find the landing field and to land by night without illumination, and by day in fogs of average opacity.

Directional instruments.- Compasses: The compasses may be magnetic, electric, or gyroscopic. They should be compensatable and capable of withstanding vibrations and temperature variations from 50 to -30°C (122 to -22°F.).

In France there are three types of liquid magnetic compasses, classified as follows:

Constant	Long distance navigation	Ordinary navigation	Orientation
Precision equal to that of direct view of a rose with a diameter of	12 cm(4.72 in.)	7 cm(2.76 in.)	5 cm(1.97 in.)
Return to zero	Exact	Exact	Within 2°
Damping period for a deflection of 45°	Under 45"	Under 30"	" "
Displacement for one rotation in 30"	Under 12°	Under 8°	" "
Balancing period	Over 3"	Over 3"	" "

They must all have quadrantal and semicircular compensation.

The Vion Company has made three compasses corresponding to the above classification and giving perfect satisfaction (Figs. 7-9). The ingenious compensation is effected by revolving groups of magnets controlled by milled knobs (Fig. 10). An index, attached to one of the toothed wheels supporting the magnets, makes it possible to place them in a position for which the group is without action.

The quadrantal compensation is accomplished with two masses of soft iron attached to two toothed aluminum wheels. A knob makes it possible to impart to the two wheels equal rotational motions in opposite directions. When the two reference marks on the wheels coincide, the action of the compensators is zero. The Vion Company is now putting the finishing touches on a com-

pass with a vertical scale.

The Vion compasses for pilots are provided with a magnifying prism, while the compasses for the observers have standard alidades.

<u>Legend for Figures 7-10</u>.- Liquid compasses each having a case provided with a support for attaching in eight positions and new compensation devices. Figure 7 represents the compass Q.S.C.25, which has a rose of 60 mm (2.36 in.) diameter with divisions of 5° each. It is rendered luminous by radium salts. It has constant, semicircular and quadrantal compensations. Figure 8 shows the navigation compass Q.S.C.27, with an 85 mm (3.35 in.) rose and 2° divisions; electric illumination by diffused light and auxiliary illumination by radium salts; magnifying prism; constant, semicircular and quadrantal compensations (The Vion bearing plate, with standard removable alidade, is shown in place). Figure 9 shows the long-distance navigation compass Q.S.C.27, with 140 mm (5.51 in.) divided into degrees. It has the same characteristics as the navigation compass (Fig. 8) plus the band compensation. The semicircular compensation is employed on the Vion compasses, types Q.S.C.25 and Q.S.C.27. The simultaneous and opposite rotation of two sets of magnets mounted on toothed wheels (Fig. 10) renders it possible to regulate the intensity of action of one compensating set on the compass, in a fixed predetermined direction. The action of another set,

in a perpendicular direction, can be regulated in the same way, which makes it possible to effect the semicircular compensation. The quadrantal and band compensations are based on the same principle.

Commander Morel had a compass of great precision made by Krauss (Fig. 11), which answers all the requirements of aerial navigation. It is compensated by magnets and soft irons movable vertically on screws by means of adjusting knobs. Commander Morel has recently invented a compass with a vertical scale. His compasses for pilots are provided with covered reflectors, while the ones for observers have bearing plates.

The Aéra Company is also constructing a navigation compass fulfilling the requirements, but without quadrantal compensation.

Drift indicators.- These should make it possible to measure the drift and the speed with reference to the ground, should be easily operated in all kinds of weather, eliminate all calculations, give for the measured angle of drift the same precision as the compass used, give the ground speed within 2% and not require previous identification of the landmarks.

In 1922 the S.T.I.Aé. (Service Technique et Industriel de l'Aéronautique) produced a drift indicator, which was subsequently improved by Badin. A system of parallel wires is oriented according to the apparent motion of objects on the ground. The ground speed is determined by the time required for a landmark to

cover the space between two wires perpendicular to the course followed. These two wires are separated, according to the altitude, so as to determine, on the ground, with respect to a sighting point situated at a fixed height, a base of constant and known length.

Captain Philippe invented a drift indicator based on the same principle. It has a rectangle of wires with a single wire in the middle, the sights being fixed with respect to each other. The whole can be mounted on the outside of the fuselage. The Impar and Vaucanson Companies have constructed interesting models of this instrument.

Mr. Dugit invented an optical drift indicator, a telescope with two lenses and two prisms behind them. The symmetrical systems of images of the ground furnished by the prisms are seen simultaneously in a single eyepiece. When the edge of the prisms is parallel to the direction of motion of the airplane, the images of the ground move parallel with it in the same direction.

The most perfect drift indicator is the well-known Le Prieur "navigraph." The graphic record of the relative path of the airplane with respect to the ground eliminates the errors due to rolling, pitching and yawing. The sight makes it possible to determine the drift from distant points. The circular calculator makes it possible to solve graphically all the navigation problems and to keep the diagram of the operations (Fig. 12).

<u>Legend to Figure 12</u>.- At the left, the latest Impar drift indicator, derived from the Philippe-Impar indicators, with its independent eyehole. In the middle, the Impar socket-and-turret mount. On the right, the latest "Le Prieur navigraph."

The Impar Company has recently made two interesting Dubois drift indicators, as shown in Figs. 13-14.

<u>Legend to Figure 13</u>.- The D.-I. drift indicator enables simultaneous measurements of drift and ground speed by sighting at any point up to 55° for or aft and 30° laterally. It consists of an eyehole, which is movable on a graduated transverse bar and which can take two positions (fore and aft) defined by stops on its slide bar. The graduated bar can, moreover, be moved parallel to itself along a square beam attached to the support. The eyehole is carried by this support whose lower part carries two semicylindrical rods graduated in centimeters. Two slide pieces connected by an elastic thread slide on these rods. The instrument is mounted so it can be inclined longitudinally in order to offset variations in the line of flight of the airplane. To make a measurement, it is only necessary to place the eyehole, by means of its three movements, in such a position that the chosen landmark is about to enter the field determined by the lower rods. At the instant the landmark cuts the front edge of the front rod, a stop watch is started and the end of the elastic thread is brought to the point of intersection. The rear slide

piece is then moved in such manner that the landmark will follow the thread and the stop watch is stopped at the instant the landmark crosses the rear rod. The drift is determined by finding the difference between the graduations covered by the elastic thread on the lower rods and by reading on one of the lateral faces of the upper bar the graduation in degrees which is found at the height of the graduation, as read on the top of the same bar, corresponding to the distance found. The speed is obtained by the simple reading of an abacus or nomogram giving V in terms of the altitude, of the time of passage, and of the drift. The instrument can be instantaneously mounted on fixed supports, on either side of the fuselage and can be folded flat and taken in, when not in use.

Legend to Figure 14.- The D.-I. pilot's drift indicator consists of a mirror so placed that the pilot, without moving, can see the ground behind. This mirror turns on a vertical axis and its position is determined by graduations on the lateral control dials. A vertical-wire alidade, with the axial line of the mirror, determines a sighting plane in which the pilot must hold his eye. Measuring the drift consists in turning the mirror, by means of one of the control knobs, so that the image of the ground point will move parallel to the axial line of the mirror. After obtaining this point, the drift is read on the left dial, if the drift indicator is on the right, and vice versa. The speed is read in terms of the altitude and of the time of passage

of a landmark between two transverse marks at the top and bottom of the mirror, the pilot keeping his eye at the intersection point of the sights passing through these marks and through the threads of the two small slide pieces on the alidade. The instrument can be mounted instantaneously on either side of the fuselage on permanent fixed supports by means of dovetail sockets. The supports are so arranged as to enable adjustments for variations of the line of flight of the airplane. The same is true of the alidade slide pieces, which can be moved vertically for this purpose.

Pelori or bearing plates.- These are instruments for taking bearings from distant terrestrial points, or from stars in order to determine one's location over the sea or above clouds, and for measuring drift by using landmarks behind the airplane. The Impar Company and the Claude and Hatton Company have made pelori which are easily read and give satisfactory results.

Legend to Figure 15.- Impar Pelorus: p, fixed plate graduated for drift; c, movable circle graduated for taking bearings; a, i, j, alidade and its hinged arms; k, conical foot for mounting. The special device for shutting the alidade is also shown.

The Vion Company has constructed a pelorus (Fig. 16), whose alidade can also be used on navigation compasses of the same make (Q.S.C.27). The pelorus is provided with a special device

which enables instantaneous and accurate adjustment on its support.

Mr. Duval had a recording pelorus made by the Aéra Company. The celluloid plate, on which the sighting lines had been drawn, is placed on the map in such a way that the marked lines pass through the chosen landmarks.

Circular calculators.- These are for determining mechanically the elements of the velocity triangle, the ground speed being obtained in the order either of the air speed of the airplane and of the wind velocity, or of the wind velocity and of the air speed of the airplane. The Duval and the Leroy circular calculators, made by the Aéra Company, solve these problems. The Richer-Protche calculator, made by the Société Optique et Précision de Levallois, is used in the Naval Air Service.

Course indicators.- These are designed to furnish the pilot permanently with the indication of the estimated point, by automatically drawing on the map the path followed by the airplane. Mr. Mengden has constructed a very interesting instrument, described in No. 92 of L'Aéronautique. The ground speed of the airplane or its two component vectors (air speed and wind velocity) are resolved according to their rectangular directions. The two speed vectors thus obtained are applied, after suitable reduction, one to the unrolling of the map and the other to the lateral displacement of a stylus. The speed of the airplane is

given by an air-speed indicator and the direction of flight by a remote selenium compass (Fig. 17). The wind velocity and direction, calculated as usual, are introduced by hand by means of an electric motor controlled by a rheostat and by a rose rotating in front of a fixed index.

Sextants.- For astronomical navigation by airplane, where the natural horizon is not always visible, sextants with an artificial horizon have been invented. The requisite precision is about 10'. The Coutinho bubble sextant is made by the "Precision moderne." The Fave dial, made by Ponthus and Therode, has been tried on airplanes. The Carpentier Company is working on a new sextant with gyroscopic level.

Map holders.- The Guer and Mansuy map holders, made by the Aéra Company, enable the reading by night, without dazzling, by interposing, between the lamp and the map, a spherical screen of blue glass. A knob enables their orientation at the will of the user.

Mr. Ramondou has had an ingenious map holder of large capacity made by the Merville Company (Fig. 18). The reels can be separated from each other on the periphery of the cylinder forming the instrument, which causes the map to occupy the same space, regardless of how much of it may be on one reel or on the other.

Mr. Melin has made a less bulky map holder, designed especially for single-seaters, as already described in L'Aeronautique.

The map rolls up and unrolls like a window curtain and may be held open by a button.

Watches.- Standard case; functioning duration, 36 hours; precision, 30" to 1' for 24 hours; temperature range, -30 to 50°C (-22 to 122°F.). The Aéra, Allion, Saint Esprit, Lipman and Ulmann Companies supply the air service with satisfactory watches.

Stop watches are indispensable for aerial navigation. They must have a seconds hand giving fifths of a second with return to zero and a totalizer of the minutes. Required precision, 10" for 24 hours.

Altimeters and barographs.- Standard case. Four types: from 0 to 1200 m (3937 ft.), 0 to 4000 m (13123 ft.), 0 to 7000 m (22966 ft.), 0 to 10000 m (32808 ft.), with equidistant graduations in altitude. The discrepancies E between the true pressures and the pressures read must be less than 2 mm (0.08 in.) of mercury for the 1200 m altimeter and less than 5 mm (0.2 in.) for the others. Types 1-2 must stand temperatures between -25 and 40°C (-13 and 104°F.); types 3-4 between -40 and 40°C (-40 and 104°F.).

The barographs are placed in rectangular cases of standard dimensions, made of wood or light metal, with four supports near the angles. Type 1, from 0 to 4000 m; type 2, from 0 to 7000 m. Toleration E, 5 mm (0.2 in.) of mercury. Temperature range: type 1, from -25 to 40°C; type 2, from -40 to 40°C. The record-

ing cylinder is of three types: for one hour, four hours and eight hours, with a tolerance of ten seconds per hour.

The Richard Company makes entirely satisfactory aneroid barometers. The same firm also makes a Bourdon-tube barograph (Fig. 19a), which gives very good results, and a very accurate 0-1200 m (3937 ft.) altimeter (Fig. 19b,c), suspended by springs inside the standard collar (Fig. 19c) required by the French technical services.

The Aéra Company makes Gourdou-Leseurre altimeters which meet the required conditions. Good results have been obtained with a Gourdou-Leseurre barograph in which the deformations of the diaphragm are transmitted to the recording needle by a spring.

Statoscopes and variometers.- These are designed to enable an airplane to maintain a given altitude and to measure climbing speeds. The Aéra Company makes a simple Badin variometer for measuring vertical speeds and a variometer of great precision, which renders it possible to follow altitude variations meter by meter. The very sensitive manometer is connected with an antithermal reservoir of air. It also communicates, through a tube, with the outside air. When this tube is closed, the manometer shows the pressure variations of the air at the different altitudes in relation to the fixed pressure of the reservoir, which remains that of the desired altitude.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.

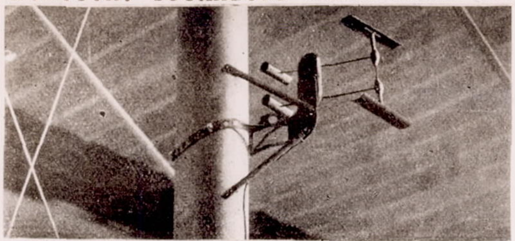

Fig.1 The Constantin indicator installed on an airplane

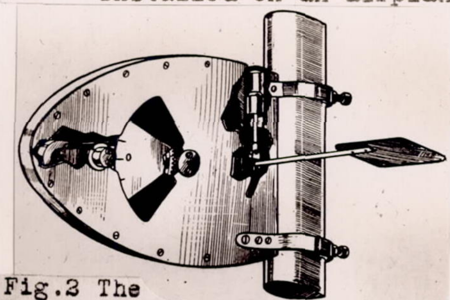

Fig.2 The Estienne-Du Cluzel indicator

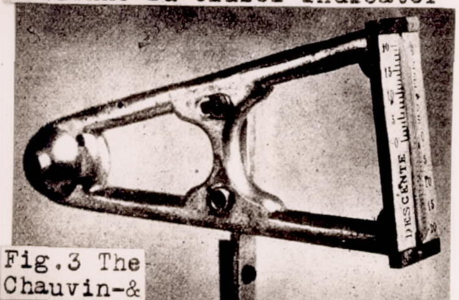

Fig.3 The Chauvin-& Arnoux longitudinal inclinometer

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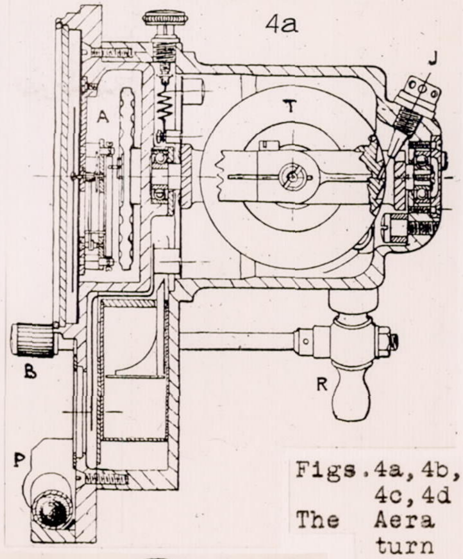

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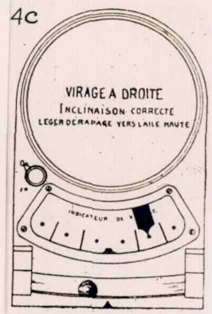

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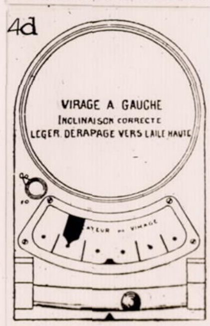
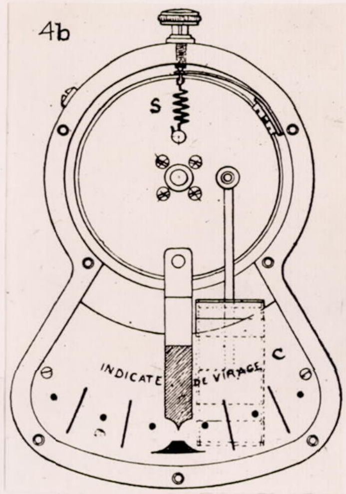
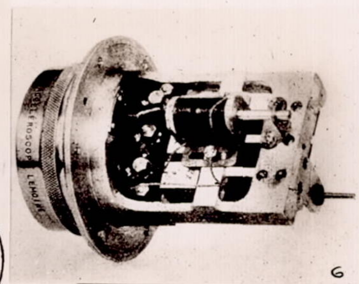


Figs.4a,4b, 4c,4d The Aera turn indicator. (Badin patent)

4b





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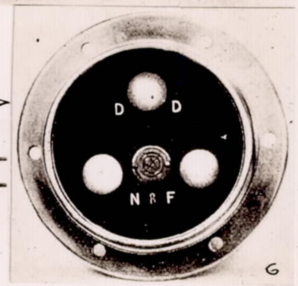

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Fig.6 The Lemoine acceleroscope, with suspended tared mass and luminous indicating device.

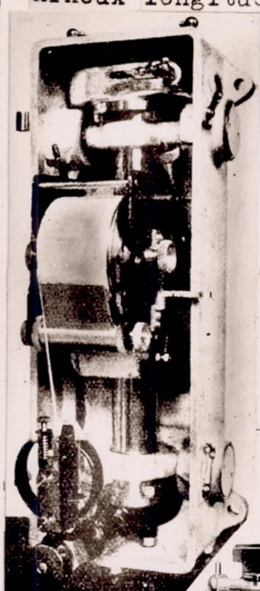
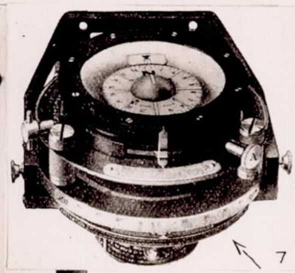


Fig.5 The Huguenard, Planiol and Magnan accelerograph.



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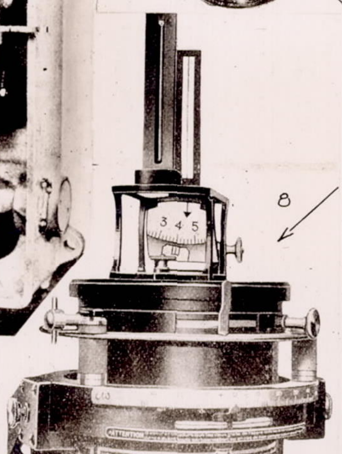

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Figs.7,8,9,10 Vion compasses for the various requirements of aerial navigation.

"Taken from L'aéronautique Sept. 1927"

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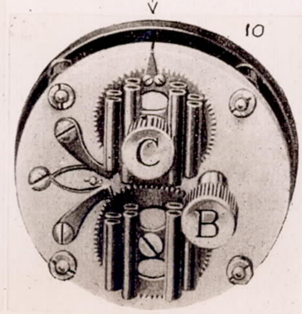

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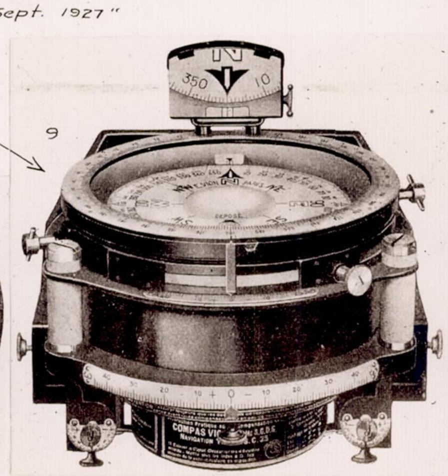

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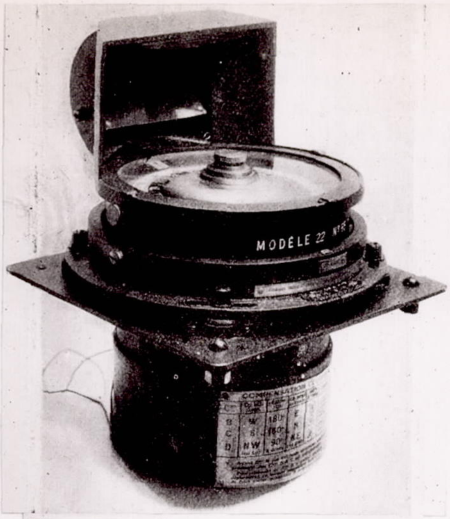


Fig.11 The Morel compass (made by Krauss)

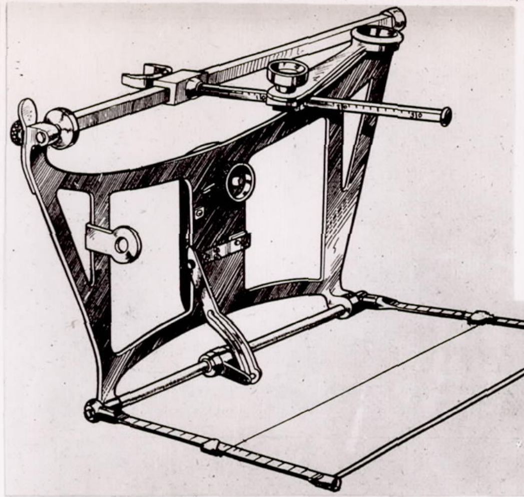


Fig.13 The Dubois-Impar "Cinemo" drift indicator.

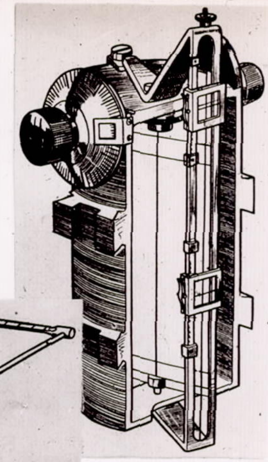


Fig.14 Dubois-Impar pilot's drift indicator.

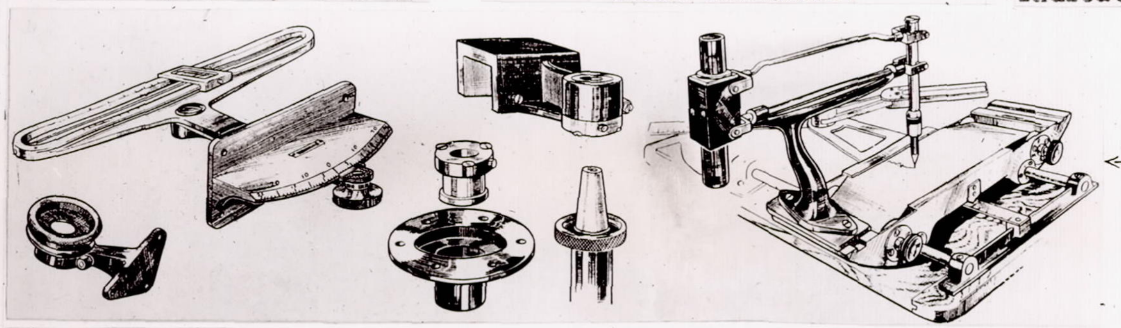


Fig. 12 Drift indicators.

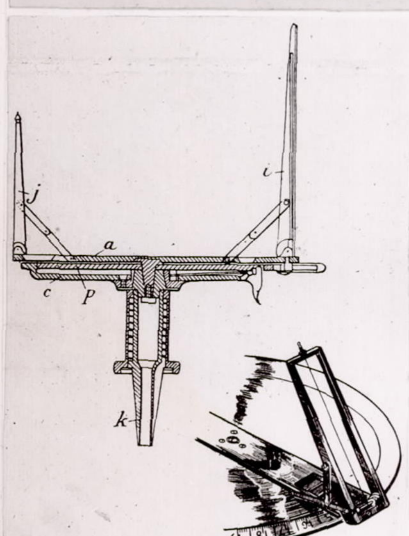


Fig.15 Impar pelorus

Fig.16 Vion pelorus

Fig.17 Remote selenium compass of the Mengden "auto-estimograph"

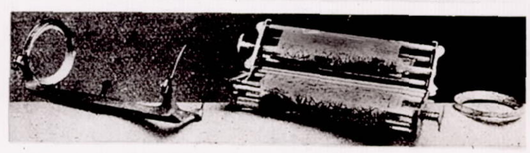
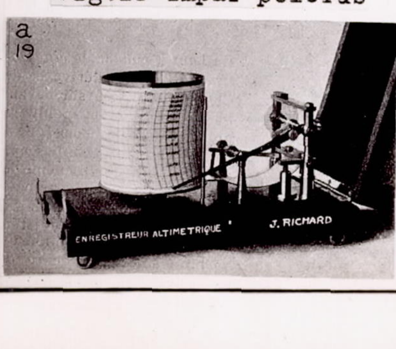
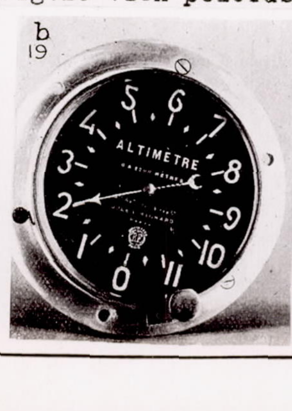


Fig.18 Ramondou map holder.

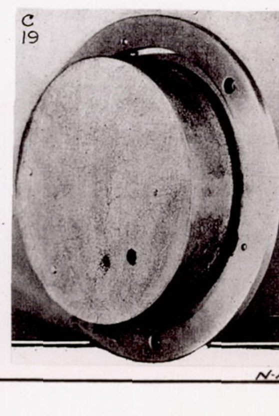
a 19



b 19



c 19



"Taken from L'aéronautique Sept. 1927"

Figs.19a, 19b, and 19c Richard barograph and altimeter.